Putting Some Pop Back in Your Crop: Alfalfa in Crop Rotations

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While alfalfa is often recognized as the "Queen of the Forages", corn may be considered "King of the Crops" and currently ranks as the nation's largest acreage crop with over 87 million acres. The corn acreage U.S. has continued to increase in recent years for various reasons including greater market demand, a shift towards larger farms that focus on a fewer number of crops, and the development of improved varieties and management practices. According to the U.S. Census of Agriculture, the acreage devoted to corn and soybeans has risen by 64 and 255%, respectively, over the last 30 years, while the land use for alfalfa and pasture has declined by 15 and 28% over the same period. The loss of forages is particular evident in the Mid-western states where acreages of alfalfa and pasture has averaged 67 & 53%, respectively. Despite a shift to "corn-centric" agriculture, the use of perennial forage species, such as alfalfa or tall fescue, in crop rotations are vital to the long-term success of grain crop operations.

Specific Benefits of Forage Species in Crop Rotation

There are many benefits that may be received through the use of crop rotations, regardless of the specific species used, such as diversifying the operation to minimize financial risk, interrupting the lifecycle of various diseases/insects, and adding flexibility to the weed management program. Forages may provide several additional benefits over other grain crops. Forage legume (e.g. alfalfa, clovers, etc.) have the ability to form a symbiosis with *Rhizobia* that converts inert, atmospheric N into plant available forms thereby reducing the need for N fertilizers. Perennial forages provide year-round vegetation that decreases the loss of soil and nutrients through erosion. The extension root system of the species also leads to increases the deposition of C into the soil that leads to improvements in other traits associated with soil quality, such as soil aggregate stability, bulk density, water infiltration, etc. The goal of this article is to detail the unique advantages that forage species may provide over other grain crops when used in rotation with corn. When applicable and when sufficient data was available, a meta-analysis (an analysis that essentially combines the published results from multiple experiments) was performed in order to determine the "true" impact forage species may have in these systems.

Providing an Economical Source of N and Opportunities for Greater Nutrient Cycling

While soybeans may also have the ability to form a symbiosis with Rhizobia, they tend to fix less atmospheric N than forage legumes. The results of the meta-analysis show that N fixed by alfalfa would replace nearly 130 lbs of N fertilizer in the first year corn (Fig.1). Red clover produced a similar N fertilizer replacement value (NFRV) as alfalfa (107 lbs N/acre). Soybeans, however, had a NFRV that was approximately half of these forage species (55 lbs N/acre). While soybeans are undoubtedly capable of fixing more N, the lower NFRV is likely a result of its grain production. The grain of soybean is exceptionally high in protein (~40% CP) and a large portion of the N provided by the Rhizobia symbiosis is allocated to the seed during grain fill. The small N credit received from soybean is primarily due to the N mineralized from fallen leaves and roots. The N fixed by perennial forage legumes is more evenly distributed between aboveground herbage and reserves within the roots so that more N is retained in the field following harvest. The amount of N provided by soybeans, although lower than forage legume, is still a respectable quantity that will still likely have an economical benefit to producer. However, this benefit has little effect beyond the next growing season due to the annual growth habit of the crop. Because forages are typically a multi-year phase (2-3 year) in the rotation cycle, the N fixed by forage legumes is compounded annually and results in a larger reservoir that is slowly mineralized in subsequent years. This is evident by the fact that alfalfa and red clover still capable of replacing a sizable portion of the N requirement (NFRV: 40-65 lbs N/acre) of corn planted two years after these forages, while as very little N was present from soybeans (Fig. 1).

It should be noted that the N credit received from forages may be further improved if the crop is used as pasture. Alfalfa and red clover were primarily harvested as hay in articles used for the meta-analysis. In pasture, there is greater potential to return N, as well as most other nutrients, to the field as only 20-40% of soil nutrients found in the forage are removed by grazing livestock compared to nearly 80-100% with the harvest of the herbage as hay. This can have a profound impact on the amount of fertilizer required by the subsequent corn crop. For example, a cool-season grass hay, such as tall fescue or orchardgrass, with a yield of 3.25 tons DM/acre would remove approximately 120 lbs N, 40 lbs P_2O_5, and 175 lbs K2O on an acre basis. Grazing of the field would restore roughly 80 lbs N/acre, 30 lbs P_2O_5, and 120 lbs K_2O/acre, which corresponds to 70%, 60%, and 58% of corn's requirement of these nutrients, respectively. Allowing stover to remain on the field following the harvest of grain crops may also promote some cycling of soil nutrients, but its nutrient content is

considerably lower than forage herbage and may lead to other agronomic issues if present in high quantities.

Increasing Soil C and Its Effect on Soil Quality

In addition to improving soil fertility and nutrient cycling, incorporating forages into a crop rotation may improve soil quality by supplying an abundant source of C. An excellent review on the contribution of forages to soil C and organic matter (OM) has recently appeared in the February issue of Progressive Forage Grower (http://www.progressiveforage.com/forage-production/management/soil-organic-matter-the-secret-to-successful-farming) so this topic will on briefly be covered here. In short, the extensive root system of forage species combined with the tissue turnover that results from frequent defoliations provides a pool of C in the soil that effectively acts as "glue" that holds soil particles together making more resistant degradation and improving soil structure. This improvement in soil structure leads to a greater infiltration and retention of water, a reduction in soil bulk density, and better aeration of the soil. Rotation with other grain crops may also increases soil C, especially under no-till operations, but reported benefits received are typically less than those found with rotations including forage species. A long-term rotational study in Iowa found that a 2 year rotation into alfalfa improved soil C by 25% compared to continuous corn. Rotation with small grains improved soil C by 10% over the same period, while incorporating soybeans into the system had minimal changes in soil C. The stability of soil aggregates was increased by 35, 17, and 1% for the alfalfa, small grain, and soybean rotations, respectively, indicating a larger potential for forages to improve soil health.

The Net Effect of Rotational Crop on Corn Yields

The results of the meta-analysis of how each rotational crop will affect corn grain yields are shown in Figure 2. Each of the crop species included in the analysis would be expected to increase grain yields compared to a continuous corn system. This represents the previously mentioned general benefits of crop rotation that may occur with any crops. The analysis showed that there were two clear statistical groups in the increases in corn yields. Rotation into other grain species (e.g. soybeans or small grains) would result in moderate increases in yields (~13 bushels/acre). Forage species or small grains interseeded with forage legumes (usually red clover) resulted in the largest yield increases (~20 bushels/acre). Interestingly, there was no difference in corn yields between alfalfa and forage grass pastures (Fig. 2). This suggests that the nutrient cycling and C deposition that results in pastures may have as large or greater impact than simply providing large quantities of N. It is also worth noting

that the yield increases from forages may be actually be greater than estimated with this analysis. The length of the forage phase for the majority of the studies included in this analysis was shorter than what most producers would utilize in their operations. Approximately 92% of alfalfa and 70% of grass pastures phases lasted 2 years or less, and as discussed, the benefits received for incorporating forage species into a crop rotation are enhanced as the length of this phase is increased.

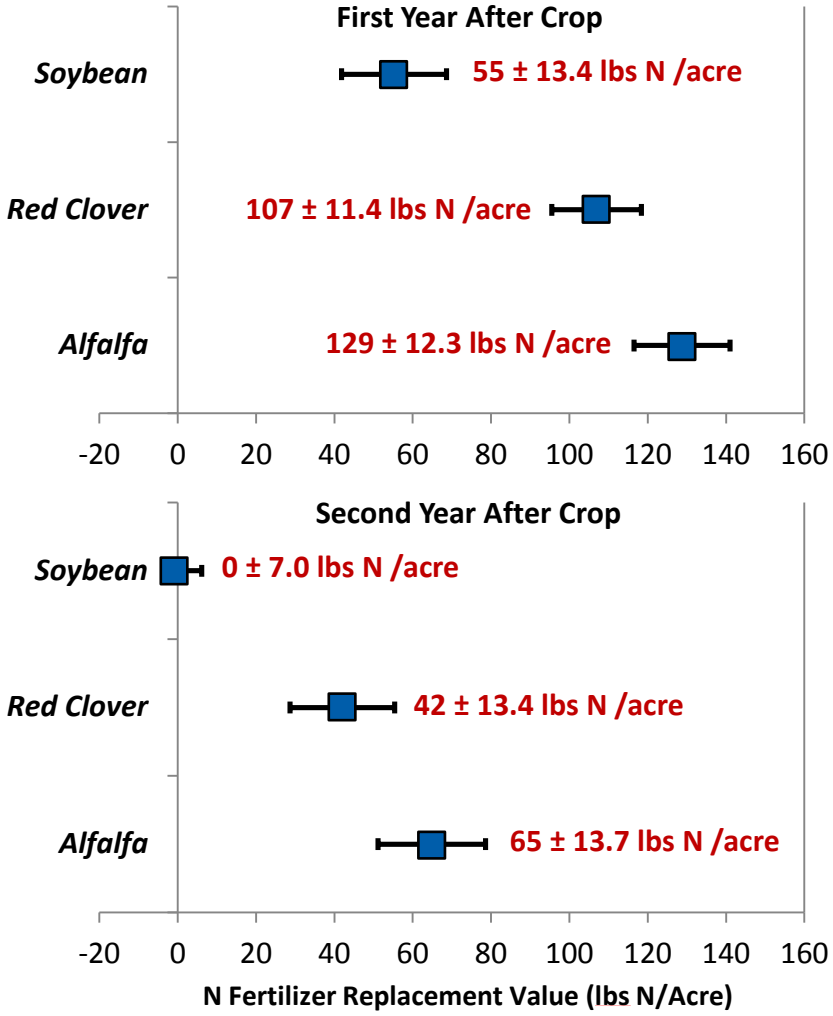

Figure 1. Expected N Fertilizer Replacement Value (lbs N/Acre) of Leguminous Crops in Corn Systems.

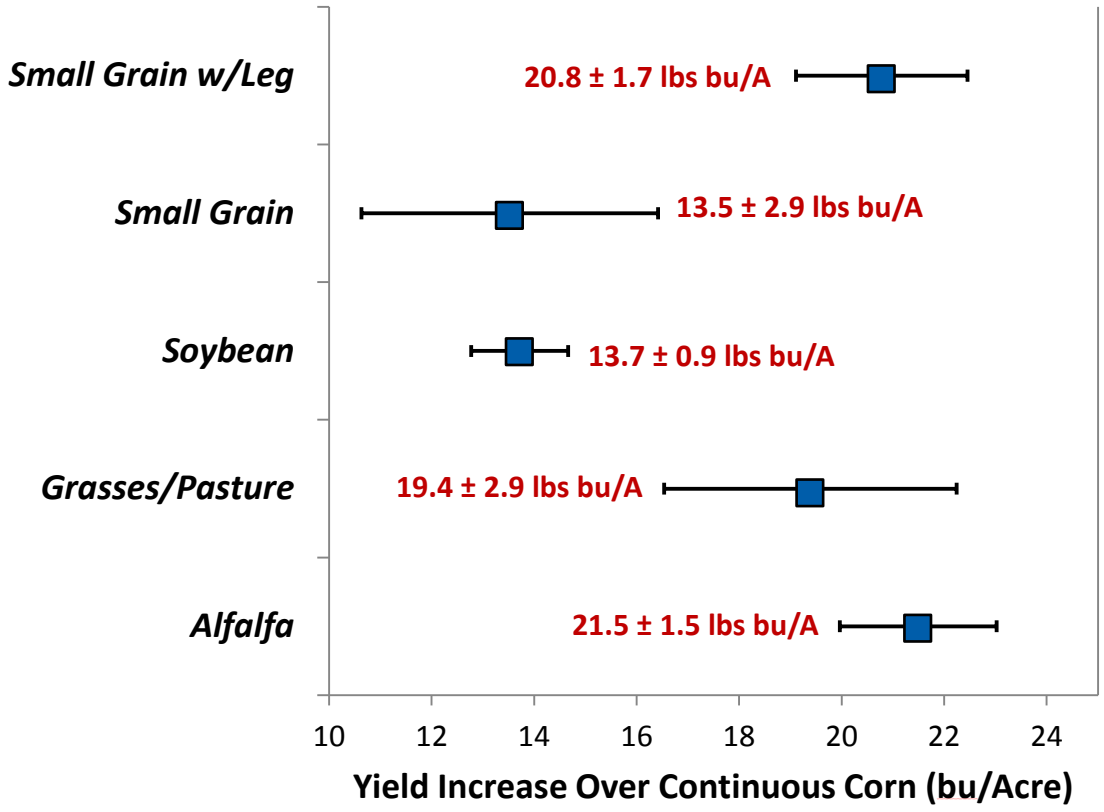

Figure 2. Expected Increases in Corn Grain Yield (bu/Acre) in Various Rotational Crops Relative to Continuous Corn.